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Impact of industrial pollution on the population dynamics of *Mytilusgalloprovincialis* in the coastal region of El Jadida(Atlantic coast, Morocco)

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Keywords

- ✓ Growth parameters
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- ✓ Morocco

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Abstract

The aim of this study is to evaluate the impact of industrial pollution on the parameters of the population dynamics of the mussel*Mytilusgalloprovincialis*, namely the asymptotic length (L∞), the growth coefficient (K) of the Von Bertallanfy equation and the recruitment profile and establish the length-weight relationship to determine the type of allometry. To achieve these objectives, three stations (S1, S2 and S3) were selected based on their proximity to industrial effluents (chemical complex of Jorf-Lasfar, Morocco). Mussel sampling (N=100/station) was performed monthly for 1 year. The biometric parameters measured are total weight, weight of flesh, length, width and thickness. The processing of the data was carried out using the FiSAT program version 1.2.2. The first results obtained show that the growth parameters estimated in the mussels from the nearest station releases (S3) are significantly lower ($L\infty$=40.00mm and K=2.01yr^{-1}) compared to the other stations ($L\infty$=57.75mm and K=2.11yr^{-1} for station S3). The recruitment pattern appeared to be unimodalfor S3 and bimodal for S1and S2. The determination of the different regression lines reveals the existence of good correlations (r^2> 0.8) between the length and the total weight. Moreover, the mussels collected from the different stations have a lower allometry (b <3, p<0.05). Indeed, the total weight increases proportionally but less quickly than the length.

1. Introduction

The Moroccan Atlantic coast extends for about 3500 km. It has considerable biological diversity and fish resources. This coastline is the object of numerous attacks caused by human activities, developed mainly along the Atlantic coast. The region of El Jadida-Safi is characterized by urban agglomerations and important industrial infrastructures, in particular the phosphate processing units. These various human activities generate a non-negligible contamination of the littoral environment, in particular by heavy metals. Moreover, the coastline of the El Jadida region shows higher levels of Cadmium in the mussel *Mytilusgalloprovincialis*[1] and in seawater and sediment [2-3]. This metallic pollution can affect the quality of the environment and threaten its ecological balance, while endangering human health.

Several authors propose the implementation of a biomarker-based approach to evaluate the stress induced by pollutants. These biomarkers can be measured at three different levels: cellular (sensitive and rapid response), tissue (assessment of organ damage) and the whole organism (assessment of survival potential and growth and reproduction performance) [4].

In this study, we opted for the biomarkers measured throughout the whole organism and the population. Indeed, the study of the biology and population dynamics of *Mytilusgalloprovincialis* is of considerable scientific interest and may provide basic data required for any commercial exploitation of the mollusc, as well as its use in coastal biomonitoring. It is widely used in a variety of monitoring programs to establish the spatial and

temporalvariability of pollutants [5-6-7]. According to Amiard and Amiard-Triquet [8], the study of the growth of these bivalves is useful in many ways because it represents the reflection of a more global response of the organism and would make the effects of contamination on the organism and potentially on the population.
The present study aims to evaluate the impact of industrial pollution on the population dynamics of the mussel *Mytilusgalloprovincialis* from different stations selected according to their proximity to the release of the chemical complex of JorfLasfar. This study consists on the one hand, in measuring the physico-chemical parameters of the sea water collected from the different stations prospected during the study period and on the other hand, comparing the growth parameters and the length-weight relationship to identify the type of allometry and to determine if there's a possible adaptation of these bivalve molluscs to the conditions of the surrounding environment.

2. Material and Methods

2.1. Location of the prospected stations
To achieve the objectives of this study, three stations were selected according to their proximity to industrial effluents of the chemical complex of JorfLasfar, (Morocco Phosphorus-III-IV, JLEC, SONASID ...) coastline at the coast of the region Jorf- Lasfar (El Jadida) (Figure 1).

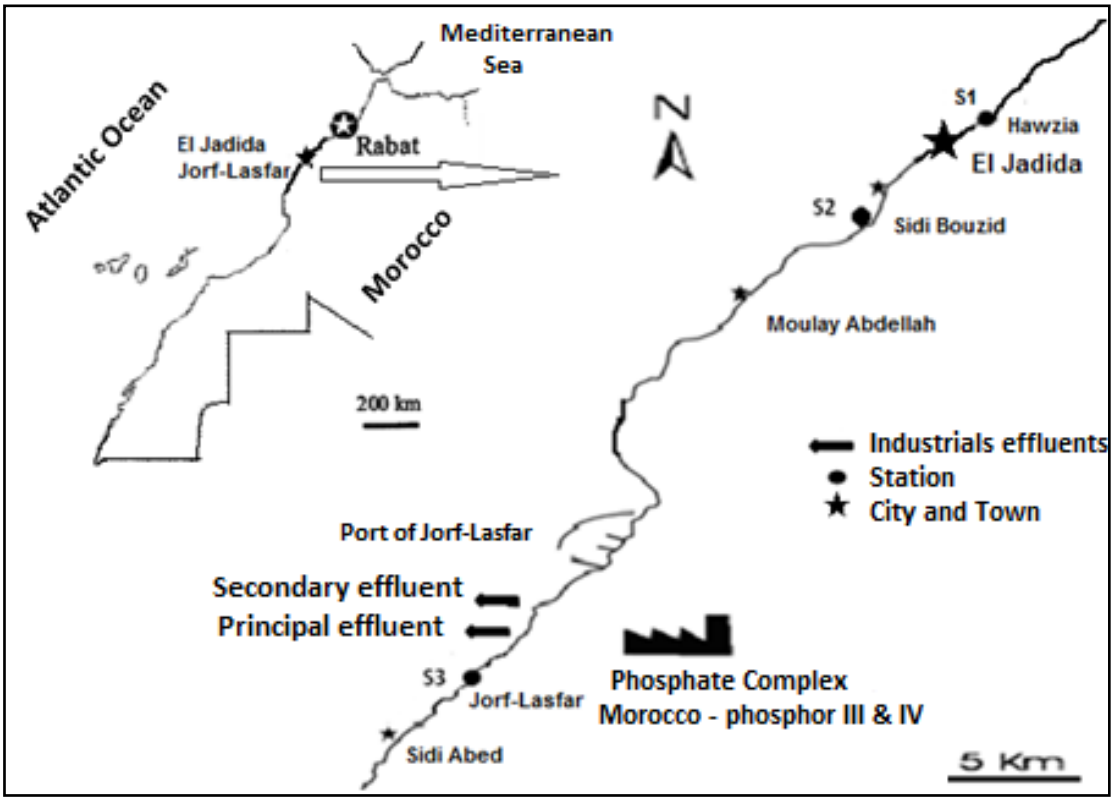

Figure 1 :Geographical location of prospected station.

**Station "Hawzia" (S1)*: located at 1 km north of the city of El Jadida and 28 km north of chemical complex effluents. This site is characterized by the absence of a source of pollution.
**Station "SidiBouzid" (S2):* this is a beach resort located at 5 km from the city of El Jadida and 17km north of the industrial effluents of Jorf-Lasfar, characterized by the upwelling causing a ride up of deep water charged with nutritional elements. This station is also characterized by the absence of releases of different types.
**Station "Jorf- Lasfar" (S3):* located at 25 km south of the city and 1 km south of industrial effluents. This site is characterized by the presence of several industrial units including the phosphate complex Morocco phosphate III and IV and a thermal power station. This is an large industrial area with the largest port in Africa. The metal concentrations are very high, far exceeding international standards [1-9].

2.2. Measurement of physicochemical parameters
The physicochemical parameters, namely temperature (°C) and pH, were measured in sea water collected at stations surveyed using a portable multi-parameter (Odeon Open X). These measurements were carried out throughout the study period from February-2016 to January-2017.

2.3. Samples and preparation of mussels

Sampling of mussels was carried out randomly at the intertidal zone during the period from February 2016 to January 2017 at differnts stations studied. 100 individuals per station per month were collected and transported to the laboratory in a cooler and then cleaned and stripped of their epibiontes and then weighed andmeasured. They are then sorted by sex and size class.

For each sample, different linear parameters (length (L), width (la), thickness (Ep)) of each individual were measured using a caliper (1/20mm accuracy). Individuals mussels were then weighed using a balance (KERN 440-33, accuracy 0.01g) measures running the weight parameters (total fresh weight (W), weight of the shell (Ws) Fresh weight of the flesh (Wf)).

2.4. Growth parameters

The model used to describe the growth of *Mytilusgalloprovincialis* and knowledge of various parameters relating to the dynamics of the population in the various stations studied is that of Von Bertalanffy (1938) [10-11]. This considers growth as the simultaneous action of anabolic factors proportional to the surface and catabolic factors proportional to the volume of the body. The law of linear growth is expressed by the equation:

$$Lt = L\infty[1 - e^{-K(t-t0)}]$$

Where Lt = mean length at age t; L∞= asymptotic length; K = growth coefficient; t = age of the *Mytilusgalloprovincialis* and t_0 = the hypothetical age at which the length is zero [12].

The growth parameters of VBGF namely the asymptotic length (L∞) and the growth coefficient (K), were estimated using ELEFAN-I [13] of the FiSAT program Version 1.2.2. [14] in both sexes combined. It is the most common tool used to estimate the growth parameters in fish, crustaceans and bivalve molluscs [15-16-17]. The advantage of this technique is that it requires only length frequency data and allows evaluating the exploitation levels and the population dynamics of a species within one year. Estimates of Lα and K were used to calculate the growth performance index (φ ') [18] using the equation:

$$\emptyset' = 2\log_{10} L\infty + \log_{10} K$$

2.5. Length–weight relationship

The different measurements performed in the mussel collected in three stations studied (100 ind / station / month) were used to study the allometric relations linking the linear and weight parameters. To establish the length-weight relationship, $\mathbf{W = a.L^b}$ was applied [19-20], where W is weight (g), L is total length (mm), a Intercept (condition factor) and b is the slope (relative growth rate). The parameters a and b were estimated by linear regression least squares on the transformed data logarithmic Log_{10} W = Log_{10} a + b Log_{10} L. Parameter b is used to determine the type of allometry that links weight to height of the animal. The coefficient of determination (r^2) was used as an indicator of the quality of linear regression [21].

2.6.Statistical Treatment of Results

The growth parameters were calculated using analysis software and data processing FiSAT II version 1.2.2. The correlations and the different regression relationships between the measured variables were carried out using the Excel software.

3. Results and discussion

3.1. Physicochemical parameters:

During the study period, measurements of temperature and pH revealed seasonal fluctuations in all the studied stations (Figure 2). Moreover, the highest temperature values were recorded at station S3 during most of the study period. This station also has the lowest pH values which oscillate between 6.4 and 7.5.

3.2. Growth parameters

A comparison of the growth parameters of the Von Bertalanffy equation (VBGF) obtained in the mussels (combined sexes) from the different studied stations reveals a significant difference depending on their proximity to industrial effluents. Indeed, the mussels from station 3 (Figure5), located 1 km south of chemical complex effluents, have the lowest values of asymptotic length (L∞=40.00mm) and higher than that of the growth coefficient (K=2.01yr^{-1}) compared to station S1 (Figure3). The estimated values for the mussels adhered at the stations S1 and S2 are of the order of 50.00mm and 57.75mm for L∞ and 1.33$yr^{-1}$and 2.11$yr^{-1}$for K respectively (Figures3, 4). The mussels of station S2 exhibit faster growth. The growth curves described by the

VBGF show a difference in linear growth and the maximum length reached in the mussels from the prospected stations.

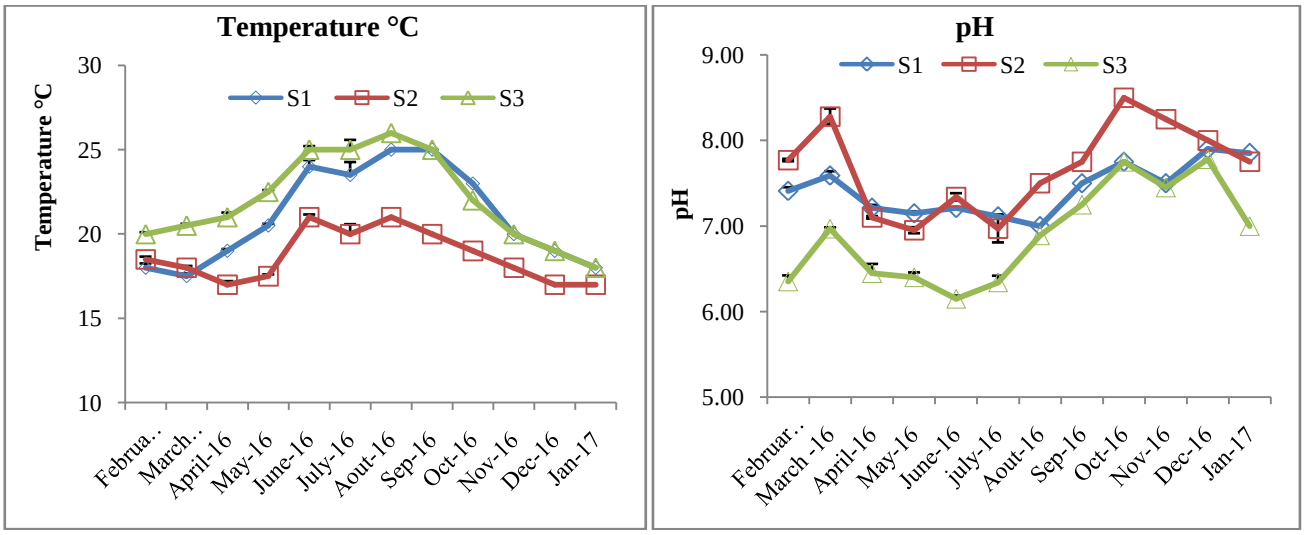

Figure 2 : Temperature and pH of marine water at stations S1, S2 and S3.

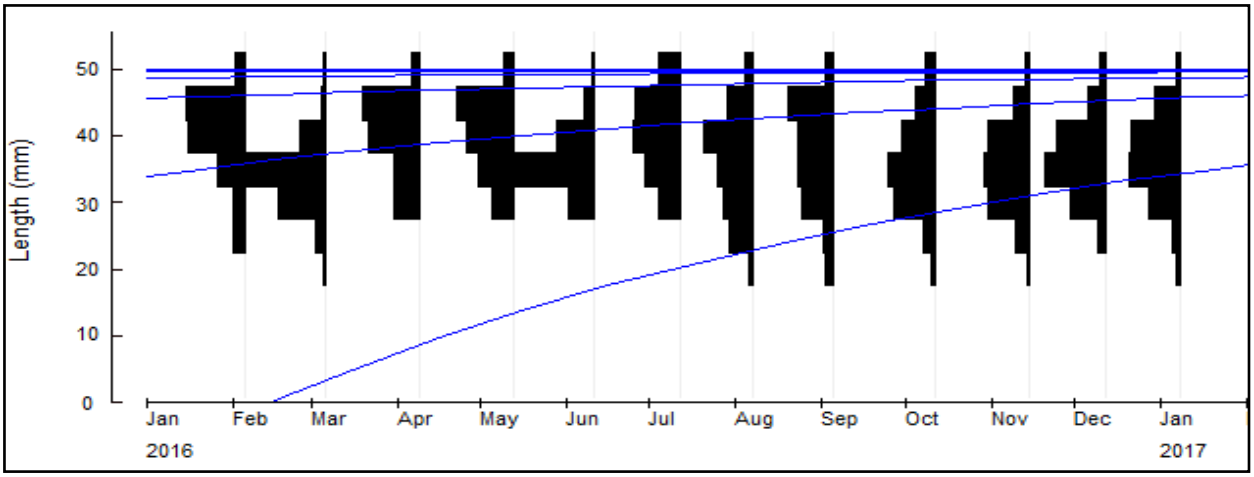

Figure 3: Von Bertalanffy growth curves (VBGF) of *Mytilusgalloprovincialis*collected from station S1 superimposed on the restructured length-frequency histograms
(Data obtained using the ELEFAN-I software for L∞=50mm and K=1.33yr $^{-1}$)

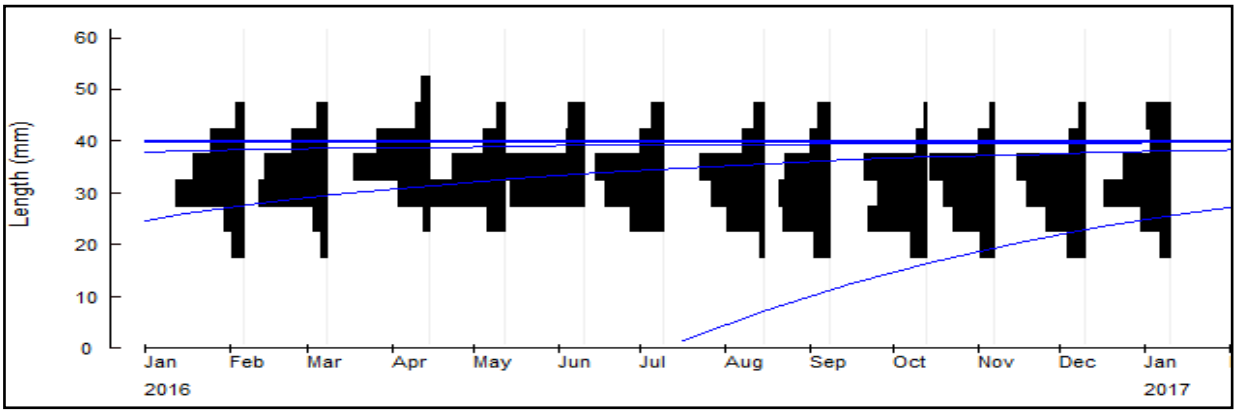

Figure 4: Von Bertalanffy growth curves (VBGF) of *Mytilusgalloprovincialis* collected from station S2 superimposed on the restructured length-frequency histograms
(Data obtained using the ELEFAN-I software for L∞=57.75mm and K=2.11yr $^{-1}$)

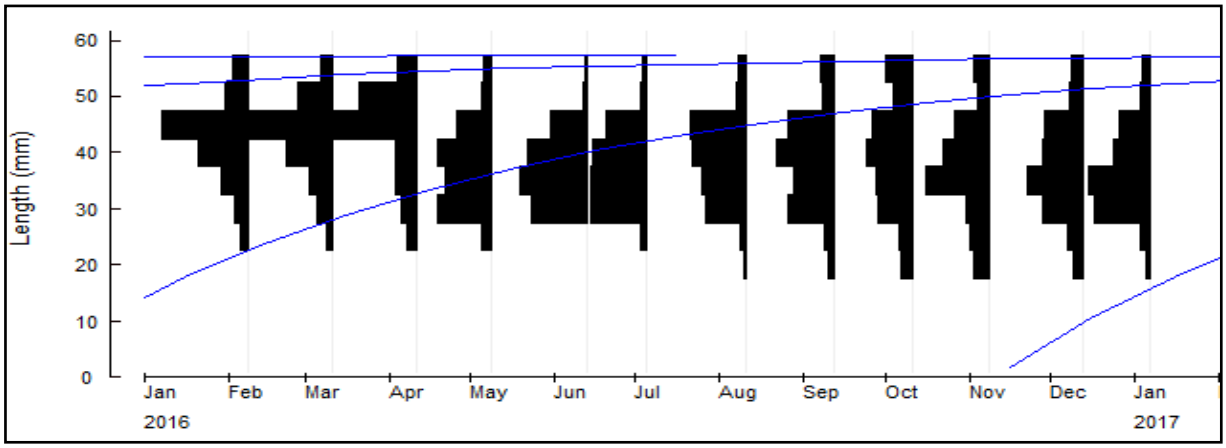

Figure 5: Von Bertalanffy growth curves (VBGF) of *Mytilusgalloprovincialis* collected from station S3 superimposed on the restructured length-frequency histograms
(Data obtained using the ELEFAN-I software for $L\infty$=40mm and K=2.01yr $^{-1}$)

3.2. Recruitment pattern

The recruitment pattern of mussel*Mytilusgalloprovincialis* taken from stations S1 and S2 characterized by the absence of any source of pollution is bimodal with the appearance of two peaks during the period of study ranging between February 2016 and January 2017 (Figures6, 7). However, in mussels from station S3, the recruitment profile is unimodal with a single major peak observed in June-16 with a recruitment percentage of 18% (Figure 8).Growth performance index (φ') estimated using the routine ELEFAN I presents the highest value in mussels station S2 (φ'=3.826) (Figure 7). This index records a value of 3.512 and 3.507 respectively in the musselscollected from the stations S1 and S3 (Figures6,8).

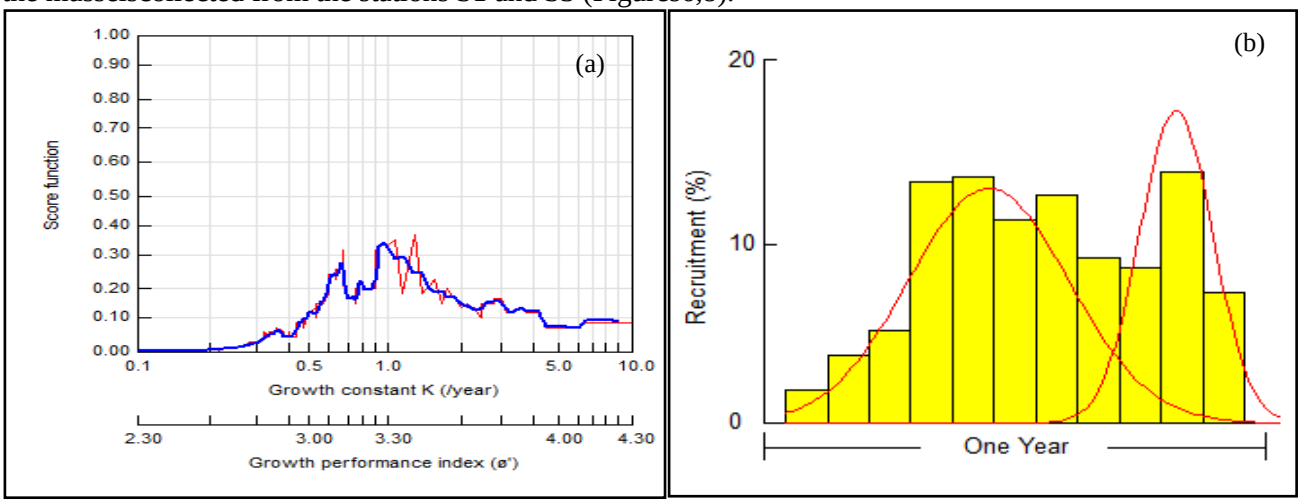

Figure 6: Growth performance index (φ) (a) and annual recruitment pattern (b) of *Mytilusgalloprovincialis* from S1.

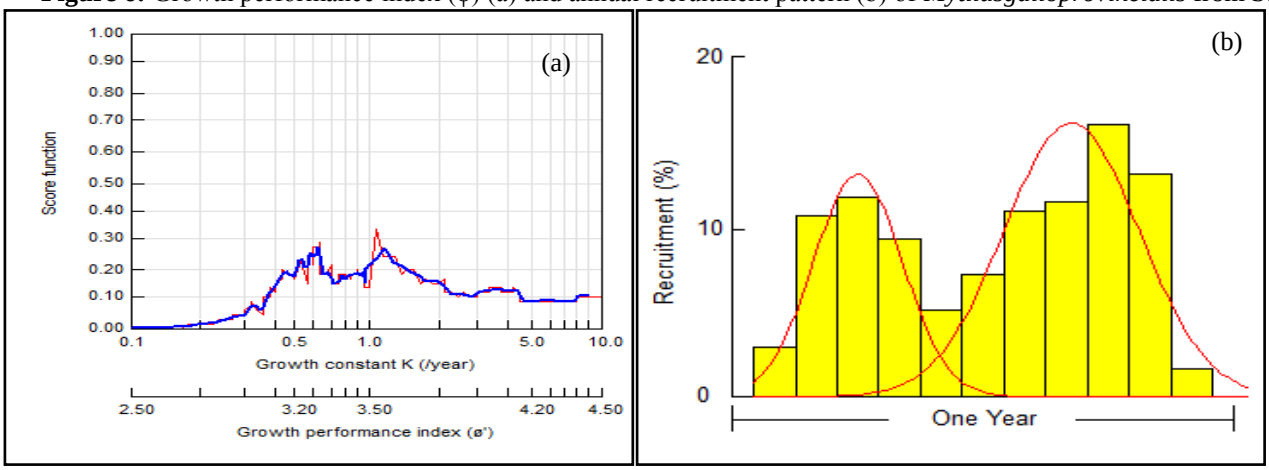

Figure 7: Growth performance index (φ') (a) and annual recruitment pattern (b) of *Mytilusgalloprovincialis* from S2.

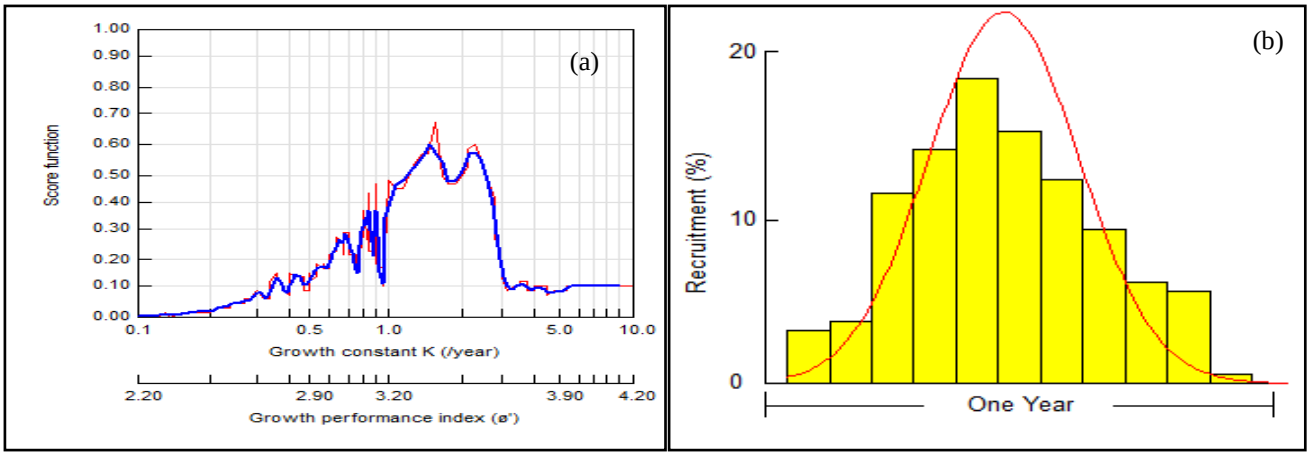

Figure 8: Growth performance index (φ') (a) and annual recruitment pattern (b) of *Mytilusgalloprovincialis* from S3.

3.3. Length-Weight Relationship

The Length-Weight Relationship was studied for both combined sexes of the mussels. The parameters of the equation: $\mathbf{W = a\ L^b}$ are represented graphically in the figure 9 for the mussels collected from the three stations, the estimated parameter b is less than "3", which translates an allometry which means that the weight grows proportionally but less quickly than the length in the mussels. The calculated correlation coefficient shows a strong correlation between the total weight change and the length with R^2 of 85.4% and 83.95% for S1, which shows that the change in total weight per The length is at the same speed.

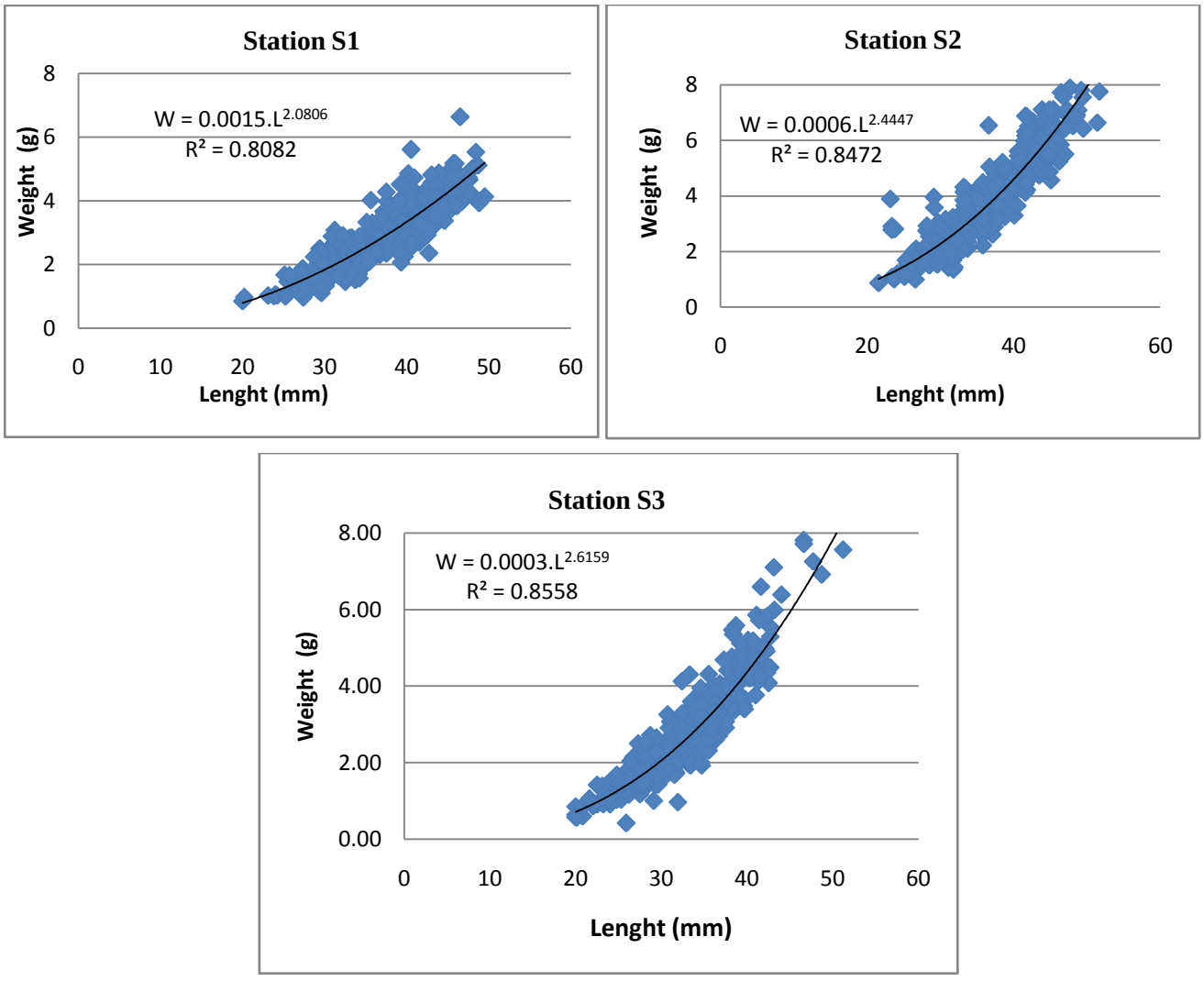

Figure 9: Length weight relationship in the combined sexes of the *Mytilusgalloprovincialis* from the studied sites

4. Discussion

The analysis of the physico-chemical parameters of the sea water collected at the three stations studied (Haouzia, Sidibouzid and Jorflasfar) revealed a seasonal variation with a warm period from June-16 to Oct-16 with a slight decrease in pH at the station closest to industrial effluents (S3). SidiBouzid site is characterized by the presence of Up-Wellingscurrents which explains the low temperatures recorded at the station S2. In the case of bivalve molluscs, several factors, such as the physical and nutritional state of the environment [22-23] and physiological parameters [24] have a direct effect on growth performance by influencing their rate of linear growth and weight.

The growth model of Von Bertalanffy has been widely applied in fisheries sciences, particularly in the analysis of fish growth. It has also found application in studies of bivalve and other invertebrates [25-26-27]. In this study, the comparison of the growth parameters recorded in *Mytilusgalloprovincialis*from the different prospected stations revealed significant differences during the study period. Indeed, the asymptotic length of the Von Bertallanfy equation estimated in the population of mussels from station S3 is significantly lower ($L\infty$= 40.00 mm) compared to the other stations. However, the growth coefficient K which is considered to be a measure of the rate at which the animal develops is higher ($K=2.01yr^{-1}$) than that recorded ($K= 1.33yr^{-1}$) in the mussels of the Station S1, the furthest from the chemical complex releases. Station S2 has the highest values of these parameters ($L\infty$ = 57.75mm and K = 2.11 yr^{-1}). This station is characterized by the presence of the Up-Welling current and by the absence of any source of pollution. Note also that the model of recruitment estimate by the software FiSAT is unimodal in the molds of the station S3.

This can be explained by the fact that the environmental stress generated by metallic pollution in the mussels of the Jorf-Lasfar site (S3) [1-9-3] and of high radioactivity in the water, sediment and mussel flesh of this site [28] has no adverse effect on the growth rate of mussels. Indeed, some adaptation of the mussels to environment conditions can be noted by the storage of heavy metals in metallothioneins[29-30]. However, it should be noted that during the same study period, measurements of the condition index and the gonad index were established in the mussels of stations S1, S2 and S3 [31]. The results obtained from the mussels of station 3 showed that these indices, which give us an idea of the physiological state of the animals, are similar to those obtained at station S2 located 17 km north of the effluents and characterized by the absence of any type of industrial as well as domestic pollution.

Although stations S1 and S2 are located far from the source of industrial pollution, a difference in growth parameters was observed. Indeed, the mussel from the station S2 have a longer asymptotic length and a higher growth coefficient. This is probably due to the immersion time which is higher in the mussels of this station. According to Summer [32], a prolonged immersion time in the bivalve mollusc*Crassostreagigas* represents a longer period of nutrition for the animals and a more stable environment with respect to climatic variations. This partially explains the beneficial effect of a prolonged immersion time on observed growth.

The evaluation of the results of the length-weight relationship recorded in the mussels of the different stations shows no difference between the stations surveyed during the study period. Indeed, a lowering allometry is observed between these two parameters in the different stations. According to Romeo and al. [33], this would be related to the monthly fluctuations in the physiological state of the animal. According to Le Pennec [34], weight dynamics is closely related to the reproductive activity of individuals. It is disturbed in bivalves by processes related to reproduction.

The same type of growth has been reported by many authors who have studied the growth of mussels and oysters in rearing [35]; The latter show that the growth in length would be related to the variations of abiotic factors such as temperature, pelagic and benthic habitat and biotic factors such as age, sex or the stage of maturity of the gonads.

Conclusion

The main results obtained in this study reveal a difference in the demographic structure of the mussel population from prospected stations with a unimodal distribution of the mussels of the station near to the industrial effluents and bimodal distribution in the mussels from the stations S1 and S2. Linear growth was studied according to the VonBertalanffy model. The parameters of the growth equation were estimated at $L\infty$ = 57.05 mm, K = 2.11 yr^{-1} in the mussels (combined sex) from the S2 station. The rate of growth in length is more different in the mussels of the three stations. Mussels from the Jorf-Lasfar site, the closest to the rejects, grow relatively quickly compared to the mussels at the Houzia site, 28 km north of the rejects, but reach a maximum length $L\infty$ = 40.00mm lower. Relative growth was studied by the size-weight relationship ($W = a.L^b$) equation. It does not show any significant difference in the mussels of the different stations. These results suggest that

there is probably a possible adaptation to environmental conditions. A complementary study on the biomarkers of pollution (metallothioneins, catalase, peroxide dismutase, acetylcholeneesterase) in the mussel *Mytilus galloprovincialis* is being processed to complete this study.

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